

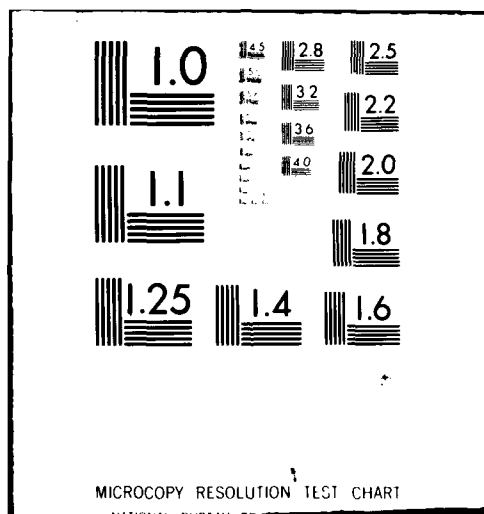
CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAIGN IL F/G 5/1  
THE SOLUTIONS DATA BASE COMPONENT OF THE WATER POLLUTION ABATEM--ETC(U)  
APR 81 J T SANDY, E D SMITH, R D WEBSTER

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Technical Report N-99  
April 1981

Pollution Abatement Management System

THE SOLUTIONS DATA BASE COMPONENT  
OF THE WATER POLLUTION ABATEMENT  
SUBSYSTEM (WPAS) OF THE POLLUTION  
ABATEMENT MANAGEMENT SYSTEM (PAMS)

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— The Solutions Data Base is divided into two subcomponents: a technical reference library and a decision-making strategy aid. It will help Army planners who develop and review designs for water pollution abatement systems perform their tasks faster, less expensively, and better by giving them all necessary technical data and setting up a comprehensive technology selection procedure.

The reference file will be searchable by either technology or pollutant and contain a narrative description of the characteristics of the technology or pollutants as abstracted from the literature.

The decision-making strategy aid will have a logic model pattern to help the Army planner define the pollution problem, identify what is needed to control the problem, select alternative wastewater treatment systems applicable to the problem, analyze design and operating conditions for these alternatives, and calculate relative construction and O&M costs for alternatives.

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## FOREWORD

This study was sponsored by the Directorate of Military Programs, Office of the Chief of Engineers (OCE), under Project 4A7626720A896, "Environmental Quality for Construction and Operation of Military Facilities"; Task T2, "Pollution Control Technology"; Work Unit 008, "Pollution Abatement Management System." The QCR number is 3.01.004.

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The work was performed by the Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (CERL).

This research was made possible through the efforts of OCE personnel, MACOM advisors, and scientific consultants from the University of Illinois at Urbana-Champaign. Administrative support and counsel were provided by Dr. R.K. Jain, Chief of CERL-EN, and Dr. E.W. Novak.

COL Louis J. Circeo is Commander and Director of CERL and Dr. L.R. Shaffer is Technical Director.

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THE SOLUTION DATA BASE COMPONENT OF  
THE WATER POLLUTION ABATEMENT  
SUBSYSTEM (WPAS) OF THE POLLUTION  
ABATEMENT MANAGEMENT SYSTEM (PAMS)

## 1 INTRODUCTION

### Background

Those requirements of Army Regulation AR 200-1<sup>1</sup> which implement the Clean Water Act of 1977 require Army installations to control the quality of their point-source wastewater effluents. Failure to do so may subject the Army to mandatory penalties. Executive Order 12088, signed by President Carter in October 1978, requires all Executive agencies to comply with the applicable pollution control standards in Federal pollution abatement legislation. It defines these applicable standards to include "the same substantive, procedural, and other requirements that would apply to a private person." It further requires that "each Executive agency shall ensure that sufficient funds for compliance with applicable pollution control standards are requested in the agency budget."<sup>2</sup>

These provisions, coupled with the high priority that the Department of the Army (DA) has placed on improved environmental management techniques, have created a need for a system to manage wastewater pollution abatement efforts. Since modern pollution control processes can be quite sophisticated, DA decision-makers face difficult technology evaluation and selection considerations. Army engineer district, major command (MACOM), and Army Pollution Abatement Program (APAP) personnel considering a wastewater treatment requirement often encounter conflicting claims of process advantages and disadvantages, uncertainties regarding process applicability, and questionable assertions regarding a technology's full-scale operational characteristics. Instead, these personnel need rapid, reliable, and inexpensive technical assistance in deciding (1) which potential pollution abatement technologies could satisfactorily meet an identified need and (2) which of the technically appropriate processes would be most economical for Army use.

To help provide this assistance, U.S. Army Construction Engineering Research Laboratory (CERL) researchers are developing a Solutions Data Base component of the Water Pollution Abatement Subsystem (WPAS) of the Pollution Abatement Management System (PAMS).<sup>3</sup> Users of this component will be able to interactively access a well-evaluated, comprehensive, and up-to-date pollution abatement technology data base by either of two methods:

<sup>1</sup> Environmental Protection and Enhancement, Army Regulation (AR) 200-1 (Department of the Army, December 1975).

<sup>2</sup> Executive Order 12088, President Jimmy Carter, 17 Oct 1978 (43 FR 47707).

<sup>3</sup> E. D. Smith and R. D. Webster, Concept Definition for the Problems Data Base Component of the Water Pollution Abatement Subsystem of the Pollution Abatement Management System (PAMS), Interim Report (IR) N-73/ADAO72398 (U.S. Army Construction Engineering Research Laboratory [CERL], June 1979).

1. All of the information on file can be retrieved randomly to answer specific questions about individual processes.

2. An additional mode of access will help the user identify that subset of all the pollution abatement technologies available which would be most appropriate for the application under consideration.

The second mode will use computerized logic, eliminating unsuitable technologies based on user responses to a series of questions. This will let the user concentrate time and attention on those processes which are most likely to meet Army needs.

### Objective

The objective of this report is to present a detailed concept definition for the Solutions Data Base component of the WPAS of PAMS and to describe the status of system development and work remaining.

### Approach

The Solutions Data Base will have two subcomponents:

1. A reference library of carefully evaluated technical information. These data, which will be presented in a standard narrative format, will cover all potentially useful chemical, physical, and biological water pollution abatement processes.

2. A decision-making strategy aid which will use a decision-tree approach to help the user select pollution abatement processes technically appropriate for Army pollution abatement problems.

The reference library will be developed by performing a comprehensive review of pollution abatement literature. Brief discussions of each important attribute of every pollution abatement technology which the Army might require will be abstracted from that literature. These brief discussions will be made interactively retrievable from computer storage.

The decision-making strategy aid will be developed by (1) identifying significant unit operations and their characteristics, (2) setting up a model decision tree, (3) compiling algorithms for the quantitative portions of the model, and (4) thoroughly testing the integrated system to ensure that it produces reliable output. This component will be computerized and made available to users in an interactive mode.

When both subcomponents of the Solutions Data Base are ready for field application, a comprehensive users manual will be prepared.

#### Mode of Technology Transfer

The technology transfer will be through field implementation of the PAMS system in accordance with AR 18-1, Policies, Procedures, and Responsibilities (Department of the Army, 1 May 1976), upon acceptance of the pilot system by DA.

## 2 RECENT REGULATIONS

### Clean Water Act of 1977

On December 28, 1977, President Carter signed into law the Clean Water Act (PL 95-217), which consists of a set of amendments to the Federal Water Pollution Control Act (FWPCA) (PL 92-500).<sup>4</sup>

The FWPCA, last significantly amended in 1972, had established a national goal that the discharge of pollutants into navigable waters be eliminated by 1985. An intermediate goal, the so-called "fishable/swimmable goal," was that "wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983." Closely related to these goals were requirements for industrial point-source discharge. Existing sources had to comply by July 1, 1977 with effluent limits based on Best Practicable Control Technology Currently Available (BPT), or with the more stringent effluent limitations based on water-quality standards reflecting secondary contact use such as fishing. By July 1, 1983, existing sources must meet effluent limits based on Best Available Technology Economically Achievable (BAT), or more stringent water-quality-based effluent limits reflecting fishable/swimmable uses, whenever attainable. New sources had to comply immediately with standards of performance based on Best Available Demonstrated Control Technology (BADCT).

The 1972 amendments to the FWPCA provided for two variances from technology-based effluent limits: (1) for dischargers of heat who can assure "the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of the water into which the discharge is to be made," and (2) for any discharger bound by the more stringent water-quality standard based on BAT who can show that the modified requirement would "represent the maximum use of technology within the economic capability of the owner or operator" and "result in reasonable further progress toward the elimination of discharge of pollutants." The industrial point-source requirements in the FWPCA's 1972 amendments are enforced through the National Pollutant Discharge Elimination System (NPDES) permit system, which incorporates the FWPCA's principle that any discharge in violation of its requirements is illegal.<sup>5</sup>

The Clean Water Act, which has nearly 80 provisions, modifies several major aspects of the FWPCA.<sup>6</sup> This law postpones the 1983 deadline for BAT to July 1, 1984 and requires that the Environmental Protection Agency (EPA) apply a test of "reasonableness" before it strengthens effluent standards for an industry that has already met the 1977 BPT. The Clean Water Act further identifies three categories of pollutants: (1) conventional (e.g., biochemical oxygen demand, total organic solids, suspended solids), (2) nonconventional

<sup>4</sup> W. Goldfarb, "Litigation and Legislation - The 1977 Amendments," Water Resources Bulletin, Vol. 14, No. 2 (April 1978), pp 491-493.

<sup>5</sup> W. Goldfarb, pp 491-493.

<sup>6</sup> "ES&T Currents, Washington," Environmental Science and Technology, Vol. 12, No. 2 (February 1978), p 129.

(e.g., metals, organic, nitrogen), and (3) toxic. There are 139 substances listed in the toxic pollutants category; these and other compounds which may be added to the list are subject to BAT control, at minimum.

#### State and Local Laws

In October 1978, President Carter signed Executive Order 12088, which required Government agencies to ensure that Federal facilities and operations comply with all state and local control standards.<sup>7</sup> It re-emphasized that Federal agencies must obey "most pollution abatement regulations" and comply with state, interstate, and local procedural regulations, "just as any private industry must do."

Executive Order 12088 applies to all Federal property and operations, including military bases, open lands, office buildings, and other structures such as research laboratories.

#### Possible Judicial Action for Federal Violators

The EPA has notified several Federal agencies, including the DA, that they must take immediate action to end water pollution at their facilities around the United States. The deputy administrator of the EPA sent a letter to the agencies in violation telling them that they must meet the same water standards as municipalities and private industry and that prompt resolution of the violations is required to avoid judicial action.<sup>8</sup>

On November 25, 1977, the EPA's Chicago office became the first of EPA's 10 regions to enforce the FWPCA against major Federal facilities. It issued 19 enforcement letters to polluting Federal installations, four of which were Army installations. To appreciate the potential extent of water pollution violations, one should contemplate the fact that the deputy administrator also listed 77 "major water-pollution sources currently not complying with Federal environmental laws," but he did not issue notices of violation to any of them.<sup>9</sup>

<sup>7</sup> Executive Order 12088, President Jimmy Carter, 17 Oct 1978 (43 FR 47707).

<sup>8</sup> "W&E Newsworthy, Legislation," Water and Wastes Engineering (March 1978), p 8.

<sup>9</sup> Environmental Reporter, Vol. 8, No. 32 (December 9, 1977), pp 1174-1175.

### 3 THE WPAS OF PAMS

The WPAS of PAMS will include:

1. A Water Reuse Model.
2. A Problems Data Base.
3. A Solutions Data Base.

Together, these components will help environmental and engineering personnel in the DA, MACOMs, installations, MACOM Facility Engineer offices, Corps of Engineers districts and divisions, the APAP, and the DA Environmental Office identify and solve Army water pollution abatement problems and effectively use Army water resources. (The relationship of the WPAS to the total PAMS system is discussed in CERL Technical Report N-42.)<sup>10</sup>

#### Water Reuse Model

Many Army installations are in arid or water-scarce regions. The Army has, therefore, long been interested in adapting water conservation, water reuse, and advanced wastewater treatment/reclamation technologies to its fixed facilities. This interest has created several total direct water reuse projects which have substantially advanced the state of the art in reuse system technology.

In 1976, the Air Force introduced a computer program called CASCADE to help its personnel identify the most cost-effective network for collecting, treating, and reusing wastewater produced at Air Force bases.<sup>11</sup> These reuse networks conserve fresh water and minimize the volume of wastewater discharged to streams or to municipal sewage systems.

CERL, in cooperation with the U.S. Army Medical Bio-Engineering Research and Development Laboratory (USAMBRDL), has adapted CASCADE for Army use. (An adaptation was necessary because of the unique activities which occur at Army installations, such as tracked vehicle washing, which have no counterparts on Air Force bases.) This modified water reuse model will be the basis of the WPAS Water Reuse Model. It will reduce the cost to the Army of sewer surcharges, advanced wastewater treatment, and raw water acquisition.

<sup>10</sup>R. D. Webster, E. D. Smith, and V. Kothandaraman, Pollution Abatement Management System -- Concept Definition, Technical Report (TR) N-42/ADA055565 (CERL, May 1978).

<sup>11</sup>General Project Report -- CASCADE System for Water Reuse at Air Force Installations (Air Force Special Weapons Center, 1 October 1976).

### Problems Data Base

To manage the environmental impact of its facilities, the Army must monitor the status of the hundreds of NPDES permits issued for Army point-source discharges. The Problems Data Base will keep a permanent record of all data submitted by plant operators of Army wastewater treatment facilities on a centralized, interactive computer system. It will compare these data to appropriate NPDES permits to (1) determine the status of compliance, and (2) inform responsible personnel of any exceptions so corrective action such as planning, budgeting, or facility upgrading can be begun.

Specifically, the Problems Data Base will:

1. Inventory water pollution point sources at TRADOC, FORSCOM, and DARCOM. This inventory could be aggregated to MACOM and DA blocks, if necessary.
2. Help monitor and report scheduled progress in water pollution abatement prescribed by Federal, state, and Army standards.
3. Allow priority ranking of water pollution problems.

(The Problems Data Base is discussed more fully in CERL Technical Report N-73.)<sup>12</sup>

### Solutions Data Base

Before an Army manager can select a water pollution abatement technology, data on process equipment, theory, life cycle costs, secondary pollution, etc., must be collected and analyzed. The Solutions Data Base helps Army planners who either develop or review designs for water pollution abatement systems perform their tasks faster, less expensively, and better by giving them all necessary technical data and setting up comprehensive technology selection procedures. The Solutions Data Base ensures that only technologies which can be confidently expected to meet the Army's treatment requirements are subjected to economic intercomparisons. This helps prevent the phenomenon of "design breakage." "Design breakage" occurs when processes selected on the basis of economics from among apparently technically equivalent treatment technologies fail to perform adequately in the field.

A complete description of the Solutions Data Base is given in the following chapter.

<sup>12</sup>E. D. Smith and R. D. Webster, Concept Definition for the Problems Data Base Component of the Water Pollution Abatement Subsystem of the Pollution Abatement Management System (PAMS), IR N-73/ADA072398 (CERL, June 1979).

#### 4 SOLUTIONS DATA BASE

The Solutions Data Base has two components:

1. A continually updated reference library of published data on pollutant removal technologies which can be used to control Army point-source discharges.
2. A decision-making strategy aid.

##### Reference Library Component

The reference library component is straightforward and easy to use. Data on each pollutant abatement technology kept in the system is in a separate file. These files are in turn organized into different sections or fields (Table 1).

These files can be searched using either technology or pollutant keywords (Table 2); once the system finds data on the topic the Army planner wants, it will display them according to the file field selected by the planner.

For example, to find information in the Solutions Data Base on suspended solids, the planner asks the system to search its pollutant abatement technology files using the keyword "suspended solids." The system will respond:

3 Processes found for this Pollutant in the "find."

This tells the planner that the Solutions Data Base has information on three abatement technologies which can be used to control suspended solids.

If, for this example, the planner wants a definition of each of these technologies, he\* asks the system to display the field "process definition and characteristics." The appendix is a sample of Solutions Data Base output.

A list of some of the technologies included in the Solutions Data Base system is given in Table 3.

##### Decision-Making Strategy Aid

The model logic pattern of the Solutions Data Base gives the Army planner a systematic way of developing a concept design phase for (1) upgrading of existing wastewater treatment facilities or (2) constructing new facilities. This logic model:

1. Defines the pollution problem.
2. Identifies what is needed to control the problem.
3. Suggests alternative wastewater treatment systems applicable to the problem.

---

\* In this report, the male pronoun is used to refer to both genders.



Table 1

Solution Data Base File Fields

title  
major pollutants  
minor pollutants  
types and sources  
other pollutants  
selectivity  
definition  
theory  
pd & e  
range  
efficiency  
equipment  
safety  
environmental impacts  
chemical considerations  
capital cost  
o & m cost  
energy  
manpower  
flexibility  
reliability  
other advantages  
disadvantages and limitations  
operating facilities  
manufacturers and designers  
new designs

Table 2

Partial List of Solution Data Base Keywords

ammonia  
coliforms  
phosphorus  
organics  
fats

oils  
grease  
iron  
aluminum  
nitrite

nitrate  
chromium  
kjeldahl nitrogen  
organic nitrogen  
suspended solids  
phenols  
cyanide  
manganese  
biological treatment  
land treatment

Table 3

Pollution Abatement Technologies

Chemical Unit Processes

Carbon Adsorption	Neutralization
Ammonia Stripping	Ion Exchange
- Counter-current	- Anion
- Cross-current	- Cation
Disinfection	
- Chemical (chlorine, bromine, ozone, etc.)	
- Physical (ionization)	

Physical Unit Processes

Grit Removal	Microscreening
Screening	Drying Beds
Comminution	Incineration
Equalization	Landfills
Flotation	Oil Separation
Thickening (gravity)	Aeration
Sedimentation (primary and secondary clarifiers)	Reverse Osmosis
Filtration	Distillation
Vacuum Filtration	Freezing
Centrifugation	Electrodialysis

Biological Unit Processes

Trickling Filters	Oxidation Ditch
Lagoons	Digestion
- Aerated	- Aerobic
- Anaerobic	- Anaerobic
Nitrification - Denitrification	Stabilization Ponds
- Combined	- Aerobic
- Separate	- Anaerobic
	- Facultative
Activated Sludge Systems	Land Treatment
- Plug flow	- Ditch irrigation
- Complete mix	- Flood irrigation
- Step aeration	- Overland flow
- Modified or high-rate aeration	- Rapid infiltration
- Contact stabilization	- Spray irrigation
- Pure oxygen	land treatment

Biological Rotating Disc Contactors

4. Analyzes design and operating conditions for these alternatives.

5. Calculates relative construction and operation and maintenance (O&M) costs for the suggested alternatives.

By defining all potentially significant definition, analysis, and design considerations, the Solutions Data Base system gives the Army planner a framework for decision development. In effect, the system is a road map; its logic guides the planner through the development of wastewater treatment alternatives, ensuring that all relevant considerations necessary for problem definition and subsequent analysis are made.

This computerized logic process helps the Army planner in two ways:

1. In the case where the planner is unfamiliar with the required treatment technology, it supplements the planner's technical skills, guiding him to the appropriate decision points.

2. In the case where the problem definition and analysis fall within the realm of the planner's knowledge and experience, it provides a series of decision points to check and confirm the manager's conceptual design.

The Solutions Data Base system meets the needs of planners with varying degrees of expertise in wastewater treatment. For example, a planner may use the system to arrive at a series of technical alternatives, perform a simplified comparison of costs, and select a number of the alternatives for more in-depth analysis. Assuming the planner's likely lack of knowledge in wastewater treatment technology, the system gives the planner a rational way of formulating alternatives. Alternatives which otherwise might have been overlooked will be examined and possibly included. At the opposite end of the user spectrum lies the experienced sanitary engineer. For this individual, the system offers a series of interactive question and response situations which will provide a check, or second opinion, on the engineer's analysis. This will help ensure that all relevant information has been taken into account in developing and comparing alternatives. The system may also suggest treatment alternatives which would not otherwise be considered by the sanitary engineer because of personal preferences or because the engineer was unaware of new developments in treatment technology. Thus, the Solutions Data Base system gives the design engineer, planner, or administrator a greater level of confidence that all facets necessary for problem definition and subsequent decision-making have been considered.

#### Model Logic Pattern

The logic model of the Solutions Data Base uses a decision-tree approach. As classically defined in the field of operations research, a decision tree is a graphic way of expressing, in chronological order, the alternative steps or actions available to the decision-maker and the choices determined by chance. The logic model of the Solutions Data Base presents alternative steps as a series of question and answer between the computer system and the user on an interactive-type terminal. Its response to answers (i.e., decisions) made by the user in reply to prompting questions will trigger subsequent questions from within the system. The definition of appropriate questions and their

chronological sequence will be founded, of course, on the underlying principles of sanitary engineering. By design, the system will guide the user through a series of questions, selected and ordered so that all relevant aspects of the suggested treatment technology are considered. (Figure 1 shows how a portion of the system could be used to assess primary sedimentation as a unit process alternative.)

The Solutions Data Base system will incorporate safeguards into its model logic pattern to prevent the user from applying system data incorrectly and, therefore, reaching a poor decision. These safeguards include such features as checking of user input data values for reasonable magnitude and units of expression and checking values calculated by the system from user-supplied data.

Because the system is ultimately constrained by the accuracy of the input data with which it is supplied, and because of time constraints on many field engineers, some decisions may be made using insufficient data. However, the Solutions Data Base's decision-tree model logic will lessen data needs for a successful decision, yet prevent its use without having adequate data. If the user does not give the system enough reliable data, the system will outline a strategy for developing the information required to formulate a meaningful decision. Therefore, the overall quality of the decision process will be improved.

In addition to providing a logic pattern for selecting wastewater treatment alternatives, the Solutions Data Base system will output preliminary cost figures (capital and O&M) for each alternative. These costs will be estimated from unit process cost curves obtained from the literature. More detailed and accurate costs could then be obtained for a selected number of alternatives by using existing models such as the Brief Input Cost Estimating Program (BICEP) and the Computer Assisted Procedure for the Designing and Evaluation of Wastewater Treatment Systems (CAPDET).<sup>13</sup>

<sup>13</sup>Brief Input Cost Estimation Program -- User's Manual (Icarus Corporation, June 1979); and Computer-Assisted Procedure for the Design and Evaluation of Wastewater Treatment Systems (CAPDET) User's Guide, Engineer Manual (EM) TIIIO-2-174 (Office of the Chief of Engineers, 29 April 1965).

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graph TD
    Start(( )) --> Q1{Do primary sedimentation facilities already exist?}
    Q1 -- Yes --> Q2{Are primary sedimentation facilities experiencing operational problems or design deficiencies?}
    Q1 -- No --> Q3{Enter settleable solids conc. in mg/l and flow rate}
    Q2 -- Yes --> Q4{Does the wastewater contain settleable solids greater than 50 mg/l?}
    Q2 -- No --> Q3
    Q3 --> Q5{Is land area available for primary sedimentation?}
    Q3 --> Q6{Has chemical addition been considered for phosphorus or SS reduction?}
    Q4 --> End1(( ))
    End1 --> End2(( ))
    End2 --> End3(( ))
    Q5 -- Yes --> End1
    Q5 -- No --> End2
    Q6 -- Yes --> End3
    Q6 -- No --> Q7{Is chemical addition required?}
    Q7 -- Yes --> End3
    Q7 -- No --> End4(( ))
    End4 --> End5(( ))
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- Figure 1. Example decision tree: primary treatment evaluation.

## 5 TECHNICAL TASKS IN MODEL LOGIC PATTERN DEVELOPMENT

The model logic pattern of the Solutions Data Base system is being developed in six steps:

1. Define significant unit operations and their characteristics (contaminants removed, treatment efficiencies, production ranges, capital cost per unit of production, and O&M cost per unit of production)
2. Develop the model decision tree
3. Develop the model algorithm
4. Evaluate the model's data and sensitivity analysis needs
5. Identify program requirements and information gaps
6. Prepare a comprehensive users manual.

### Task 1: Define Significant Unit Operations and Their Characteristics

The reference library component of the Solutions Data Base system will be developed using CERL and other Army documents and the open literature. From this investigation, wastewater treatment unit operations of use to the Army will be defined. So far, the pollution abatement technologies listed in Table 3 are to be included (many of these were abstracted from the CAPDET system). When all data needs are identified, a matrix of treatment process chains that relates unit operations to contaminants will be developed. Consideration will be given to specific treatment potentials at various production ranges and cost categories.

### Task 2: Develop the Model Decision Tree

The logic pattern the Solutions Data Base system uses to execute problem definition and analysis will actually be composed of a series of decision-tree modules nested inside a main guiding decision tree. In the computerized form, these modules will be represented as subroutines operating inside one main program. Each module or subroutine will represent one of the wastewater or sludge treatment unit operations described under Task 1. Many computerized subroutines for the preliminary design and cost analysis of wastewater unit operations, such as those in CAPDET or the EPA's EXECUTIVE and EXEC/OP programs, already exist; if it is possible, the Solutions Data Base system will adapt these existing subroutines.<sup>14</sup>

<sup>14</sup>J. E. Hendry, D. F. Rudd, and J. D. Seader, "Synthesis in the Design of Chemical Processes," AIChE Journal, 19, 1 (1973); and Lewis A. Rossman, Computer-Aided Synthesis of Wastewater Treatment and Sludge Disposal Systems, EPA-600/2-79-158 (U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, December 1979).

The basic format of the main decision tree is shown in Figure 2. Initially, separate logic pathways will analyze existing wastewater treatment facilities and possible upgrading modifications. Separate logic pathways will also be initially followed for wastewater treatment as opposed to sludge treatment. However, these pathways will not be independent, because of the inherent and necessary links keyed to sludge generation rates and the recycle of sludge processing sidestreams. Such feedback loops within the model logic are represented by the double-arrowed lines between model components in Figure 2. Using the matrix of unit operations defined in Task 1, logical pathways for decision-making in each model component will be developed.

### Task 3: Develop the Model Algorithm

Using the literature information developed in Task 1 and the decision tree developed in Task 2, a comprehensive mathematical model will be developed as follows:

1. The unit operation matrix will be modified to fit an interactive computer mode.
2. An algorithm that simulates the decision tree will be developed.
3. The decision-tree algorithm and the unit operations matrix will be computerized using a logical flow procedure. The algorithm and unit operation will be incorporated so they ensure a comprehensive management tool for preliminary decision-making on Army wastewater treatment problems.
4. The model will be constructed in a question and answer format for input operations developed for use at a CRT or hard copy time-sharing terminal. This would allow interaction between the decision-maker and the model in a "hands-on" mode.

### Task 4: Evaluate the Model's Data and Sensitivity Analysis Needs

The Solutions Data Base's model logic pattern will be stressed and its sensitivity to various components of engineering management will be defined as follows:

1. From the data base developed in the literature, the model will be stressed using maximum and minimum values for variables of concern within each of the unit operations.
2. Under these conditions of stress and sensitivity, the variables will be identified from the standpoint of their impact on model capability for projection of functional relationships.
3. The decision tree and its associated algorithms will be modified if it is found that substantial improvement could be gained in sensitivity under stress.

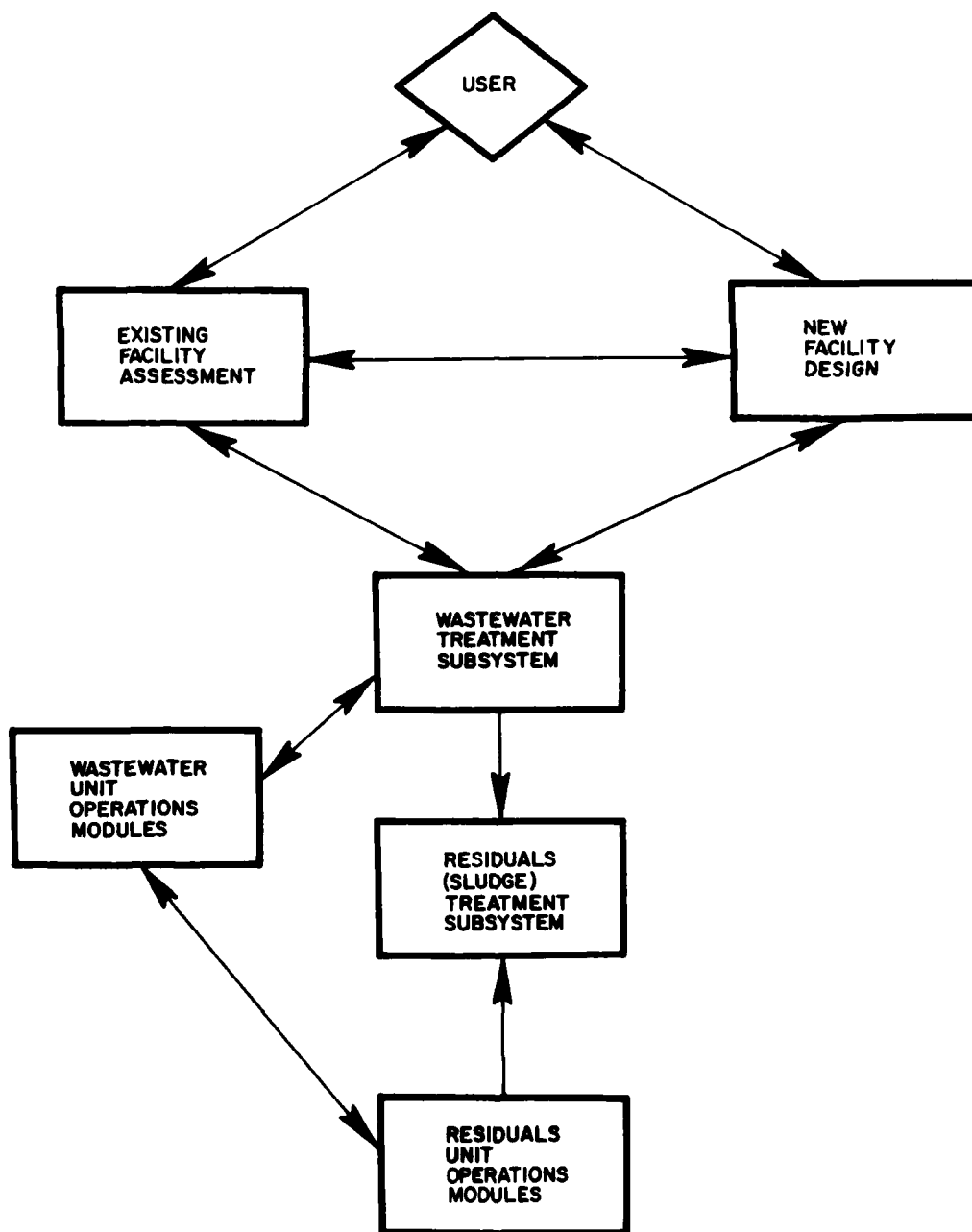


Figure 2. Decision tree format.



4. A number of complex scenarios will be developed to determine the model's effectiveness as a management tool for hypothetical situations.

#### Task 5: Identify Program Requirements and Information Gaps

The information collected during Tasks 1 through 4 will be used to identify future research efforts. Items to be addressed in this task are:

1. General needs for advanced complex computer support for decision-making within the Army as related to water and wastewater quality.
2. Special opportunities for application of new and innovative technologies.
3. Ways in which technology development in the management of wastewater treatments systems may be beneficial to industrial or municipal facilities.
4. Identification of information gaps in technology as related to the development and adaptation of the model.
5. Identification of information gaps in the data required as input to the model.
6. Discussion of the management problems associated with model use such as data quality and sensitivity.
7. Identification and prioritization of program requirements to improve implementation of advanced technologies as tools in the management of wastewater treatment as related to Army installations.

#### Task 6: Prepare a Comprehensive Users Manual

A users manual will be developed that will include:

1. A short overview of the model, its components, and limitations.
2. A section describing the model data requirements and suggested data sources.
3. A step-by-step model use procedure with examples. This section will be written in workbook format with data forms and sample data sheets. These forms will be designed so that the data can be coded directly onto computer cards, if required, or can be pulled directly from the workbook for interactive computer use in a question-and-answer input format.

## 6 CONCLUSIONS

This report has described the overall concept definition for the Solutions Data Base component of the WPAS of PAMS, which will be developed for use by DA planners and Facility Engineers to help Army installations keep their effluents within prescribed limits of quality. The concept definition has taken into account current and anticipated regulatory requirements.

The Solutions Data Base will be divided into two subcomponents: a technical reference library and a decision-making strategy aid. It will help Army planners who develop and review designs for water pollution abatement systems perform their tasks faster, less expensively, and better by giving them all necessary technical data and setting up a comprehensive technology selection procedure.

The reference file will be searchable by either technology or pollutant and contain a narrative description of the characteristics of the technology or pollutants as abstracted from the literature.

The decision-making strategy aid will have a logic model pattern to help the Army planner define the pollution problem, identify what is needed to control the problem, select alternative wastewater treatment systems applicable to the problem, analyze design and operating conditions for these alternatives, and calculate relative construction and O&M costs for alternatives.

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## APPENDIX:

### EXAMPLE OUTPUT

Welcome to the Solutions Database Information Retrieval System.

:find suspended solids

3 Processes found for this Pollutant in the 'find'.

:and organics

2 Processes found for this Pollutant in the 'find'.

2 Processes left from the 'and'.

:list definition

Process 1

1 Biological Treatment

#### Definition

Biological treatment processes remove soluble and colloidal organic matter (COD/BOD/TOC) from wastewater through the growth and metabolism of microorganisms, particularly bacteria. Under aerobic conditions, i.e., using oxygen as the final electron acceptor, the organic material which is metabolized is either synthesized into more cells or oxidized for energy to carbon dioxide and water. However, biological processes will remove only biodegradable organic matter; the organic matter which can be broken down enzymatically by bacteria and metabolized. Refractory or inert organic material is material which cannot be biologically metabolized and thus cannot be removed by biological processes.

There are a wide variety of biological processes which are in use today and can be classified into two major categories: aerobic and anaerobic processes. Aerobic processes rely on the use of oxygen as the final electron acceptor whereas anaerobic processes operate in the absence of oxygen. In this selection only aerobic processes will be considered since they are the predominant processes used for soluble and colloidal BOD removal and at this point in time, anaerobic processes are primarily used for stabilization of organic solids which is more commonly known as sludge digestion. Also, anaerobic processes used for the removal of soluble and colloidal BOD are in limited use and still in the developmental stages. However, it would appear that anaerobic processes may have a future since the organic wastes can be converted into a useful by-product (methane gas). In addition, the anaerobic filter has shown promise in the treatment of many types of wastes (2-4). On the other hand, land treatment processes which could be considered a biological process, will not be discussed in this section and will be dealt with in a separate section.

Of the multitude of aerobic processes available, there are basically two types: suspended growth and fixed film systems. In suspended growth systems, the biomass which oxidizes the organic matter in a given aerated reactor is in a suspension, with the aeration providing the required oxygen and keeping the system well mixed. In systems where the suspension is concentrated in a sedimentation tank and returned to the aerated reactor, the process is commonly referred to as activated sludge. Once through or no recycle systems are referred to as either stabilization ponds or lagoons.

Unlike suspended growth systems, in fixed film systems the biomass is attached to the surfaces of various types of media. In older types of fixed film systems, 1 to 2" diameter rock provided the surfaces for the

biomass, while currently materials such as plastics (which have superior qualities over rock) are employed. There are two types of fixed film reactors: trickling filter (TF) and rotating biological contactors (RBC). In the TF process, the wastewater passes over the top filter media and is collected from the filter bottom. Oxygen must be transferred from the air spaces in the filter to the liquid film of wastewater as it passes over the media and ultimately to the biomass which is attached to the surfaces of the media. On the other hand, RBC's have circular plastic media which rotates on a horizontal shaft. The media, which is partially submerged in a reactor, provides support for the biomass and also serves as an efficient oxygen transfer device as it rotates through the wastewater in the reactor. Unless used as a roughing process, both the TF and RBC are followed by sedimentation, which is required in order to meet most secondary effluent standards.

All of the biological processes which are aerobic are considered secondary treatment processes when followed by some form of sedimentation. Usually, primary treatment processes such as screening, grit removal, and primary sedimentation precede biological treatment processes. This is especially true in the case of the TF process, where adequate screening and primary settling are required in order to prevent clogging of the filter media.

#### Process 2

##### 2 Land Treatment

#### Definition

##### Land Treatment Processes

Definition: Land treatment processes use the soil and, in part, the vegetation growth on the soil to achieve removal of organic matter and other pollutants, from wastewaters of both industrial and municipal origin. There are three principal groups of land treatment processes, which are: irrigation, rapid infiltration, and overland flow. These three major groups of processes are currently in use today and will be covered in this section.

#### List range

#### Process 1

##### 1 Biological Treatment

#### Range

##### Normal Operating Range

Biological processes can be designed for a wide range of organic concentrations. Municipal treatment plants typically treat organic concentrations, in terms of 5 day BOD, in the range of 100 mg/l to 400 mg/l. Industrial wastes containing higher levels of BOD can be treated using biological processes. Wastes strengths as high as 10,000 mg/l or more have used biological processes.

#### Process 2

##### 2 Land Treatment

## Range

Land treatment processes generally operate in a wide range of organic loadings, with applications varying from municipal waste to high strength industrial wastewaters. Typically, in municipal wastewaters, the 5-day BOD's range from 100 to 400 mg/l. Industrial wastewaters from a food processing plant containing BOD's ranging from 300 mg/l to 1500 mg/l were successfully treated using an overland flow system (29).

## List efficiency

### Process 1

#### 1 Biological Treatment

##### Efficiency

The anticipated removals of organic matter from biological waste treatment processes depends, for the most part, on the performance of the sedimentation tanks which usually follow the process. In most suspended growth systems, for instance, activated sludge, the settling tank is an integral part of the process. On the other hand, with the attached growth reactors, clarifiers are required in order to meet discharge requirements. When the discharge standards are not as strict, as in the case of an industry discharging to a municipal treatment plant, clarifiers may not be required. The reason for the emphasis on the sedimentation basin is the conversion of organic compounds in the wastewater to microbial suspended matter. Thus, in most cases, it is a requirement to settle the suspended matter, which also exerts a BOD. While in most biological processes, the conversion of soluble organic matter to biomass can be greater than 90%, the overall removal would depend upon the physical character of suspended matter settling in the clarifier.

The following table lists the range of efficiencies one might expect from various biological processes. In general, 90% removal efficiency can be reasonably expected from most of the processes, with the exception being trickling filters, which generally have poorer effluent quality than most of the other biological processes. Also, extended aeration effluents can be more variable, which may be due, in part, to the lack of operational care. Most extended aeration plants are small package plants, typically receiving infrequent visits from plant operating personnel. For stabilization ponds, the effluent quality can be quite variable, since the effluent will contain algae. Although the BOD conversion may be 80-95%, the suspended solids, much of which is algae, may be in the range of 80-140 mg/l for aerobic ponds and 80-240 mg/l for aerated lagoons.

Reported Removal Efficiencies for Various  
Biological Processes.

Process	BOD Removal Efficiency			
	Ref. (1)	Ref. (19)	Other	Ref.
Activated Sludge				
Conventional	85-95	90-95	-	-
Complete Mix	85-95	90-95	-	-
Step Aeration	85-95	-	-	-
Contact Stabilization	80-90	85-95	-	-
Extended Aeration	75-95	90+	-	-
Carrousel	-	-	95+	13
(Oxidation Ditch)				
Attached Growth				
Trickling Filters	-	80-85	-	-

Process 2

2 Land Treatment

Efficiency

The expected effluent quality from the three major types of land treatment systems, the irrigation, the rapid infiltration and the overland flow system, is shown in the following table. Effluent quality for all three systems is excellent, with the poorest being for the overland flow systems. However, the effluent from overland flow systems is good, with the BOD and suspended solids both averaging 10 mg/l. Levels of less than 10 mg/l for both BOD and suspended solids can be attained using either irrigation or rapid infiltration systems. Other pollutants such as ammonia, total nitrogen, and phosphorus can also be reduced to low levels. In general, depending on the treatment system used, tertiary quality effluent can be attained using land treatment processes.

Expected Quality of Treated Effluent from  
Land Treatment Processes, mg/l (Ref. 1).

Constituent	Irrigation 1		Rapid Infiltration 2		Overland Flow 3	
	Ave.	Max.	Ave.	Max.	Ave.	Max.
BOD	<2	<5	2	<5	10	<15
Suspended Solids	<1	<5	2	<5	10	<20
NH <sub>3</sub> -N	<0.5	<2	0.5	<2	0.8	<2
Total Nitrogen as N	3	<8	10	<20	3	<5
Total Phosphorus as P	<0.1	<0.3	1	<5	4	<6

- 1 Percolation of primary or secondary effluent through 5 ft of soil.
- 2 Percolation of primary or secondary effluent through 15 ft of soil.
- 3 Runoff of comminuted municipal wastewater over approximately 150 ft of slope.

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